

CFP 1616 US
CRF-348
BIF022377/US

PATENT

APPLICANTS

Félix HENRY
Frédérique EHRMANN

TITLE

Compression of digital data and coding of the compressed data in order to
protect them against transmission errors

DRAFT - PENDING EXAMINER'S ACTION

5

10 The present invention concerns a method and device for compressing digital data and coding the compressed data in order to protect them against transmission errors.

15 Compression of the signal makes it possible to transmit or respectively store the digital data whilst reducing the transmission time or transmission rate or respectively reducing the memory space used.

20 Moreover, the protection of digital data against transmission errors makes it possible to obtain data which are not altered after transmission thereof. Known techniques for protecting digital data against transmission errors are for example turbocoding (described in the article by Berrou, Glavieux and Thitimajshima: "Near-Shannon limit error-correcting coding and decoding: turbo-codes", ICC 93, Geneva) or convolutional coding (described in the book by Shu Lin and Daniel J. Costello, Jr., "Error Control Coding: Fundamentals and Applications", Prentice-Hall Series in Computer Applications in Electrical Engineering, Franklin F. Kuo, Editor, 1983).

25 In this context, the invention concerns more particularly the control of the throughput of the processed data, that is to say the ability to attain a predetermined compressed file size, this size being adapted to the subsequent transmission error protection coding.

30 In order to compress a fixed image, a conventional data compression method is for example the method normally referred to as JPEG (from the English Joint Photographic Expert Group). This method does not make it possible to effect a control of the throughput. This is because the user can only

choose a quality factor which indicates approximately the compression ratio, since the higher the quality factor the lower the compression ratio. However, it is not possible to choose the size of the compressed file, except by carrying out a series of tests with different quality factors, in order to obtain the desired size.

5 With other compression techniques, it is on the other hand possible to specify before compression the required compressed file size, to within a bit. This file will then be obtained more rapidly than with an iterative method as previously described.

For example, the JPEG2000 method, still for fixed images, makes it
10 possible to generate a compressed file whose size has been specified in advance.

The present invention aims to combine a digital compression including a possibility of specifying the size of the compressed file, with a coding of the compressed data in order to protect them against transmission errors,
15 adapting the compressed file to the constraints related to the transmission error protection coding.

To this end, the invention proposes a method of adjusting at least one parameter for the compression of data representing physical quantities, the compressed data then being coded according to a coding mode in order to
20 protect them against transmission errors, characterised in that it includes, as from a required compressed data size, the steps of:

- determining at least one characteristic of the coding mode,
- determining an effective size of the compressed data according to the required size and said at least one characteristic,

25 - adjusting at least one compression parameter according to the effective size.

Correlatively, the invention concerns a device for adjusting at least one parameter for compressing data representing physical quantities, the compressed data then being coded according to a coding mode in order to
30 protect them against transmission errors, characterised in that it has:

- means of determining at least one characteristic of the coding mode,

DOCUMENTA
DEPOSITA
INVENTORI
ET
EXCEPTE
PROTEGENT
INVENTOREM
ET
EXCEPTE
PROTEGENT
INVENTOREM

- means of determining an effective size of the compressed data according to a required compressed data size and said at least one characteristic,
- means of adjusting at least one compression parameter according to the effective size.

The invention also proposes a method of compressing data representing physical quantities, and coding the compressed data in order to protect them against transmission errors, characterised in that it includes, as from a required compressed data size, the steps of:

- 10 - determining at least one characteristic of the coding mode,
- determining an effective size of the compressed data according to the required size and said at least one characteristic,
- adjusting at least one compression parameter according to the effective size,
- 15 - compressing the data,
- coding the compressed data.

Correlatively, the invention proposes a device for compressing data representing physical quantities, and coding the compressed data in order to protect them against transmission errors, characterised in that it has:

- 20 - means of determining at least one characteristic of the coding mode,
- means of determining an effective size of the compressed data according to a required compressed data size and said at least one characteristic,
- 25 - means of adjusting at least one compression parameter according to the effective size,
- means of compressing the data,
- means of coding the compressed data.

By virtue of the invention, the size of the compressed file is adapted to the constraints of the transmission error protection coding, and thus the quantity of useful data compressed and then protected against transmission errors is maximised.

Consequently, for a given quantity of compressed data, the invention makes it possible to maximise the quality of the decoded data.

According to a preferred characteristic, the required size is determined automatically, and notably the required size is determined according

5 to the constraints related to the subsequent decoding and compression of the data. Thus the characteristics of both the compression and coding and the decoding and decompression are exploited in order to adapt the compression and obtain a data quality which is as good as possible after processing.

According to a preferred characteristic, the coding mode processes
10 the data by groups of predetermined length, and said at least one characteristic of the coding mode is the predetermined length. Thus, for example, the adding of padding bits, which would otherwise be necessary to form groups of predetermined length, is avoided.

According to preferred alternative characteristics, the coding mode is
15 a turbocoding and the characteristic is an interleaving length of the turbocoding, or the coding mode is a convolutional coding.

According to a preferred characteristic, the adjustment of at least one compression parameter is a control of the throughput of the compressed data in order to obtain the effective size.

20 According to a preferred characteristics, combined or alternative, the compression parameter is the effective size, the resolution of the data after their decompression, or a quantisation step.

According to a preferred characteristic, the effective size is an integer multiple of the interleaving length. Thus the number of bits added during the
25 turbocoding, these added bits not being useful data, is minimised.

According to a preferred characteristic, the effective size is determined by rounding the required size. The user then obtains a file whose size is very close to that which he has specified.

The adjustment or compression and coding device has means of
30 implementing the above characteristics.

The invention also concerns a digital apparatus including the adjustment or compression and coding device, or means of implementing the

adjustment or compression and coding method. This digital apparatus is for example a digital photographic apparatus, a digital camcorder, a scanner, a printer, a photocopier, or a facsimile machine. The advantages of the device and of the digital apparatus are identical to those disclosed above.

5 The present invention also concerns a information storage means, such as a floppy disk or a CD-ROM. The information storage means, which can be read by a computer or microprocessor, integrated or not into the device, possibly removable, stores a program implementing the throughput control or compression and turbocoding method.

10 The characteristics and advantages of the present invention will emerge more clearly from a reading of a preferred embodiment illustrated by the accompanying drawings, in which:

- Figure 1 is an embodiment of a device implementing the invention,
- Figure 2 depicts a coding device according to the invention,
- 15 - Figure 3 depicts a system including a coding device according to the invention and an associated decoding device,
- Figure 4 is an embodiment of the coding method according to the invention,
- Figure 5 depicts a method of determining an order of size required,

20 according to the present invention.

According to the chosen embodiment depicted in **Figure 1**, a device implementing the invention is for example a microcomputer 10 connected to different peripherals, for example a digital camera 107 (or a scanner, or any means of acquiring or storing an image) connected to a graphics card and 25 supplying information to be processed according to the invention.

The device 10 has a communication interface 112 connected to a network 113 able to transmit digital data to be processed or conversely to transmit data processed by the device.

A second communication interface 115 is connected to an antenna 30 116 for sending and receiving data.

The device 10 also has a storage means 108 such as for example a hard disk. It also has a drive 109 for a disk 110. This disk 110 can be a

diskette, a CD-ROM, or a DVD-ROM, for example. The disk 110, like the disk 108, can contain data processed according to the invention as well as the program or programs implementing the invention which, once read by the device 10, will be stored on the hard disk 108. According to a variant, the 5 program enabling the device to implement the invention can be stored in a read only memory 102 (referred to as ROM in the drawing). In a second variant, the program can be received in order to be stored in an identical manner to that described previously by means of the communication network 113.

The device 10 is connected to a microphone 111. The data to be 10 processed according to the invention will in this case be the audio signal.

This same device has a screen 104 for displaying the data to be processed or serving as an interface with the user, who can thus parameterise certain processing modes, by means of the keyboard 114 or any other means (a mouse for example).

15 The central unit 100 (referred to as CPU on the drawing) executes the instructions relating to the implementation of the invention, instructions stored in the read only memory 102 or in the other storage elements. On powering up, the processing programs stored in a non-volatile memory, for example the ROM 102, are transferred into the random access memory RAM 20 103, which will then contain the executable code of the invention as well as registers for storing the variables necessary for implementing the invention.

In more general terms, an information storage means which can be read by a computer or microprocessor, integrated or not into the device, possibly removable, stores a program implementing the method according to 25 the invention.

The communication bus 101 affords communication between the different elements included in the microcomputer 10 or connected to it. The representation of the bus 101 is not limitative and in particular the central unit 100 is able to communicate instructions to any element of the microcomputer 10 30 directly or by means of another element of the microcomputer 10.

With reference to **Figure 2**, one embodiment of the coding device according to the invention is intended to code a digital signal for the purpose on

the one hand of compressing it and on the other hand of protecting it against transmission errors. The coding device is integrated into an apparatus, which is for example a digital photographic apparatus, a digital camcorder, a scanner, a printer, a photocopier, a facsimile machine, a database management system or
5 a computer.

The device according to the invention includes a signal source 1, here for an image signal IM, whether a fixed image or an image sequence. In general terms, the signal source either contains the digital signal, and includes for example a memory, a hard disk or a CD-ROM, or converts an analogue
10 signal into a digital signal, and is for example an analogue camcorder associated with an analogue to digital converter. The image source 1 generates a series of digital samples representing an image IM. The image signal IM is a series of digital words, for example bytes. Each byte value represents a pixel of the image IM, here with 256 levels of grey or in colour.

15 An output of the signal source 1 is connected to a data compression circuit 2 which effects a coding, known per se, of the image, referred to as source coding. For example, for a fixed image, the coding used is in accordance with the standard JPEG2000 (in English Joint Photographic Expert Group), currently being produced and a description of which is available via the
20 Internet at the address <http://www.jpeg.org/cd15444-1.pdf>.

The circuit 2 includes a colour transformation circuit 21 which transforms the images from the red-green-blue system to the luminance-chrominance system.

25 The circuit 21 is connected to a Discrete Wavelet Transformation circuit 22, referred to as DWT. The circuit 22 transforms the data which it receives into wavelet coefficients. The circuit 22 is connected to a scalar quantisation circuit Q 23, which quantises the wavelet coefficients as quantisation symbols.

30 The circuit 23 is connected to a first entropic coding module H1 24, which codes the quantised data in accordance with a block coding without loss. Each block of coded data is associated with a size data item which expresses the contribution of the block to the increase in size of the compressed file and a

distortion data item which expresses the contribution of the block to the decrease in distortion in the decoded image.

The entropic coding module H1 24 is connected to a second entropic coding module H2 25, which effects truncations in the blocks of data supplied by the module 24. These truncations are effected according to the contribution of each block of data to the increase in size of the file and to the reduction in distortion of the decoded image. Only the blocks which contribute the most to the decrease in distortion and the least to the increase in the file size are kept, until a total size is obtained which will be disclosed below.

10 The output of the compression circuit 2 is connected to the input of a channel coding circuit 3, here two-parity turbocoding in order to protect the data against transmission errors. Turbocoding is described in the article by Berrou, Glavieux and Thitimajshima: "Near-Shannon limit error-correcting coding and decoding: turbo-codes", ICC 93, Geneva.

15 A turbocoding circuit is conventionally constructed from the parallel concatenation of two recursive systematic convolutional coders and an interleaver.

The functioning of a convolutional coder can be depicted by a trellis.

As from its input, the turbocoding circuit 3 has a padding circuit 31. 20 The circuit 31 supplies a sequence of binary symbols to be transmitted, or "to be coded", a. The function of the circuit 31 is to terminate the trellis by adding tail bits or padding bits so that these bits enable the coder to terminate in the required state, generally the state "0". The fact of knowing the final state of each coder, added to the fact that the initial state is also fixed, makes it possible 25 to subsequently use the Maximum A Posteriori (MAP) decoding algorithm.

The circuit 31 is connected to a first recursive systematic convolutional coder 32, referred to as an RSC coder, which supplies, from the sequence a, two sequences v₁ and v₂ of symbols representing the sequence a.

The circuit 31 is also connected to an interleaver 33 which supplies, 30 from the sequence a, an interleaved sequence a* whose symbols are the symbols of the sequence a, but in a different order. Different types of interleaver can be used: random permutation interleaver, or reverse

DOCUMENTA
PUBLISHERS
LTD
1990

permutation interleaver, a block interleaver, or an interleaver which may be uniform or not, a pseudo-random scrambler for example.

An interleaver processes the data which it receives by series of predetermined length S.

5 The interleaver 33 is connected to a second recursive systematic convolutional coder 34 which supplies, from the interleaved sequence \underline{a}^* , a third sequence, \underline{y}_3 , representing the sequence \underline{a} .

10 The three sequences \underline{y}_1 , \underline{y}_2 and \underline{y}_3 are supplied to a modulating circuit 50, which performs conventional modulation, filtering and mapping processings, and possibly a transposed band modulation. The resulting signal is transmitted over a transmission channel by means of an antenna 51.

15 Parallel turbocodes have been considered here, but the invention applies, with adaptations within the capability of persons skilled in the art, to serial turbocodes and hybrid turbocodes (having a serial turbocoding part and a parallel turbocoding part).

The first coder 32 used here is a systematic coder, that is to say the sequence \underline{y}_1 is identical to the sequence \underline{a} .

20 The coder 32 uses a polynomial $f(x)$ as a multiplier polynomial, the coder 34 uses a polynomial $h(x)$ as a multiplier polynomial, and the coders 32 and 34 both use a polynomial $g(x)$ as a divisor polynomial.

According to the invention, a regulation interface 40 reads a required total size R_T of the coded file. The required size R_T is for example defined by the user when he effects the coding control.

25 As a variant, the required size R_T is not defined by the user, but is defined automatically. For example, the device which will receive the image fixes a maximum memory size, which is transmitted to the coder and which determines the required size R_T . This variant applies particularly in the case where the receiving device is a mobile telephone whose display memory is limited.

30 The regulation interface 40 then interrogates the interleaver by means of a length acquisition module 41, in order to know the length S of the interleaving. In a variant, the length S can be read in memory.

In order to optimise the network resource which will be used for transmitting the data, it is necessary to ensure that the actual size R of the compressed file is an integer multiple of the length S of the interleaver, that is to say $R = k.S$, where k is an integer.

5 In addition, the actual size R of the compressed file must be as close as possible to the desired size R_T . For this purpose, it is possible to round either to the multiple below or to the multiple above.

10 In order to choose the type of rounding, a predetermined reference mode, preferably able to be changed from one coding to the next by the user, is stored in a memory 42. The regulation interface interrogates the memory 42 by means of a mode acquisition module 43.

When the reference mode is "rounded to the multiple above", the actual size $R = k.S$ will be such that k satisfies the condition: $(k-1).S < R_T \leq k.S$.

15 When the reference mode is "rounded to the multiple below", the actual size $R = k.S$ will be such that k satisfies the condition: $k.S < R_T \leq (k+1).S$.

In practice, these two rounding modes correspond to two different applications.

20 In the case of rounding to the multiple above, the technical requirements related to the use of the turbocoder mean that additional resources will be used, in the case of extension of the signal with zero samples, in order to correspond to the multiple of the length S of the interleaver. In this configuration, there is an advantage in exploiting to the maximum this resource, which will in any event be used. The size of the compressed file is consequently increased from the required size R_T to the maximum value, with the advantage 25 of an improved quality of the image on decoding.

Rounding to the multiple below corresponds to the case where the requested size R_T can in no circumstances be exceeded, for example if it is wished to store the compressed file in a memory area of limited size.

30 When the regulation interface 40 has calculated the actual size R of the compressed file, this size is transmitted to a throughput control module 26, which is connected to the two entropic coding modules 24 and 25. The coding

of the image is achieved by the coding circuit 2, which then supplies a compressed file of size R to the turbocoder 3.

The turbocoder 3 codes the compressed file in order to protect it against transmission errors, and the data resulting therefrom are for example modulated and then transmitted over the transmission channel. It should be noted that the efficiency of the turbocoding is 1/3, that is to say, if the integer n represents the number of padding bits, the size of the file output from the turbocoder is $3x(R + n)$.

In a variant, the length S of the interleaver 33 can be parameterised. It is for example chosen from amongst a predetermined range of values. According to another variant, the regulation interface enables the user only to choose one size amongst multiple values of the length of interleaver S. It is then not necessary to effect a rounded calculation.

With reference to **Figure 3**, a system in which the invention is implemented includes the signal source 1, the source coding module 2, the channel coding module 3 and the regulation module 4, an example embodiment of which has just been disclosed.

The channel coding module communicates with a corresponding channel decoding module 6, via a transmission channel 5. The module 6 is connected to a source decoding module 7 which delivers a restored signal, which is for example displayed, in the case of an image, by conventional display means 8.

Figure 4 depicts an embodiment of the method of coding an image, according to the invention. This method is implemented in the coding device of Figure 1 and includes steps E1 to E10.

The method is produced in the form of an algorithm which can be stored in whole or in part in any information storage means capable of cooperating with the microprocessor. This storage means can be read by a computer or microprocessor. This storage means is integrated or not into the device, and can be removable. For example, it can include a magnetic tape, a diskette or a CD-ROM (fixed-memory compact disc).

The method includes the compression of the image and the turbocoding of the compressed image, and the control of throughput according to the invention.

Step E1 is the determination of the required size R_T .

5 The following step E2 is the determination of the length S of the interleaver. This length can take a unique value, or a value selected from amongst predetermined values.

The following step E3 is the determination of the mode for calculating the actual size: by rounding down or rounding up.

10 The following step E4 is a test on the chosen mode.

If the mode chosen is the rounding-down mode, then step E4 is followed by step E5, at which the actual size R is calculated according to the formula:

$$R = E[R_T/S].S, \text{ where } E[\dots] \text{ denotes the integer part.}$$

15 If on the other hand the mode chosen is the rounding-up mode, then step E4 is followed by step E6, at which the actual size R is calculated according to the formula:

$$R = (E[R_T/S] + 1).S, \text{ where } E[\dots] \text{ denotes the integer part.}$$

Step E5 or step E6 is followed by step E7, which is the coding of the
20 image. As disclosed previously, this coding is for example a coding of the JPEG2000 type, including a throughput control. The result of this coding is a compressed file of size R, which is transmitted to the turbocoder at the following step E8.

The following step E9 is the protection of the compressed image
25 against transmission errors, by turbocoding.

The following step E10 is the transmission of the compressed and then turbocoded image over the transmission channel, after a possible modulation.

The decoding of the data is conventional and consequently will not
30 be detailed here. It includes a turbodecoding followed by a decompression of the received data.

Figure 5 depicts an embodiment of the method of determining an order of size required by the decoding device including the modules 6, 7 and 8. (Figure 3).

The method is implemented in the form of an algorithm which can be

5 stored in whole or in part in any information storage means capable of cooperating with the microprocessor. This storage means can be read by a computer or microprocessor. This storage means is integrated or not into the device, and may be removable. For example, it may include a magnetic tape, a diskette or a CD-ROM (fixed-memory compact disc).

10 Step E20 is the determination of the memory size available for decoding. As disclosed previously, this size can be determined by the display size of the image to be restored. This size is either calculated or read from memory.

The following step E21 is the calculation of the required size R_T

15 according to the previously determined memory size.

The following step E22 is the transmission of the required size R_T to the coder including the modules 2, 3 and 4, as shown diagrammatically by the dotted line in Figure 3.

As a variant, the memory size determined at step E21 is transmitted

20 to the coder and the required size R_T is calculated in the coder, according to the memory size transmitted.

Naturally, the present invention is in no way limited to the embodiments described and depicted, but quite the contrary encompasses any variant within the capability of a person skilled in the art.

25 In particular, the invention has been described with reference to fixed images, but it applies to any type of digital data, for example video data.

Moreover, the compression parameter adjustment can be effected on the resolution of the data after their decompression, or on a quantisation step, as an alternative to or combined with the adjustment described on the effective

30 size.

Finally, the coding mode intended to protect the data against transmission errors can be convolutional coding.